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IS : 10181 • 1982

Indian Standard

METHOD FOR
DETERMINATION OF MAGNETIC
PERMEABILITY OF IRON AND STEEL

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Indian Standard

METHOD FOR DETERMINATION OF MAGNETIC PERMEABILITY OF IRON AND STEEL

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Indian Standard

METHOD FOR DETERMINATION OF MAGNETIC PERMEABILITY OF IRON AND STEEL

0. FOREWORD

0.1 This Indian Standard was adopted by the Indian Standards Institution on 12 April 1982, after the draft finalized by the Methods of Physical Tests Sectional Committee had been approved by the Structural and Metals Division Council.

0.2 The need for the preparation of an Indian Standard for determining magnetic permeability was felt as a number of material specifications require such properties to be determined. The magnetic properties of any specimen of material may be considered to be defined by the Normal Induction and the Hysteresis data. The method described in this standard is applicable to iron and steel product in any form provided the dimensions are such that necessary test pieces may be obtained. Magnetic properties of sheet specimens, however, are to be determined in accordance with IS : 649-1963*.

0.3 In the preparation of this standard assistance has been derived from the following standards:

BS 2454-1954 Methods for the determination of magnetic permeability of iron and steel bars, forgings and castings. British Standards Institution.

ASTM A341-69 Method of test for direct current magnetic properties of materials using DC permeameters and the ballistic test methods. American Society for Testing and Materials.

ASTM A342-1964 Methods of test for permeability of feebly magnetic materials. American Society for Testing and Materials.

0.4 In reporting the result of a test made in accordance with this standard, if the final value, observed or calculated, is to be rounded off, it shall be done in accordance with IS : 2-1960†.

*Method of testing steel sheets for magnetic circuits of power electrical apparatus (*revised*).

†Rules for rounding off numerical values (*revised*).

1. SCOPE

1.1 This standard deals with the determination of normal magnetization curve connecting flux density and magnetizing field of iron and steel in the form of bars, rods or strip specimens which may be cut, machined or ground from cast, compacted, sintered, forged, extruded, rolled or other fabricated materials.

2. TERMINOLOGY

2.0 For the purpose of this standard the following definitions shall apply.

2.1 Magnetic Flux Density (B) — The total steady magnetic lines of force along the test length of a specimen divided by the normal cross-sectional area in square centimetres. The unit of magnetic flux density in SI units is Tesla, which is equal to 10 000 gauss, the unit in cgs system.

2.2 Magnetizing Field (H) — The magnetic potential gradient along the test length of a specimen. The unit of magnetic field strength in SI system is ampere turn per metre, which is equal to $4\pi \times 10^{-3}$ or 0.012 57 oersted.

2.3 Normal Magnetization — The co-related maximum values of flux density (B) and magnetizing force (H) acting under uniform, reproducible cycle conditions of magnetization, established in successively increasing magnitudes. The graph of B against H is termed the magnetization curve.

2.4 Magnetic Permeability — The ratio of the magnetic flux density to the field producing it (B/H).

2.5 Magnetic Material — Material having, under conditions of normal magnetization, flux densities appreciably greater than the corresponding magnetizing field that is B/H appreciably greater than 1 gauss/oersted.

2.6 Specimen — A test piece, representative of the material upon which the test for magnetic properties is to be made.

2.7 Ballistic Galvanometer — A galvanometer serving to measure small quantities of electricity represented by transient currents, the free period of the moving parts being long compared with the duration of the transient current.

2.8 Permeameter — An apparatus for determining the relationship between flux density and magnetizing field in a specimen under steady conditions of magnetization.

2.9 Yoke — The part of the permeameter, external to the specimen, which provides a return path for the flux from one end of the specimen to the other.

2.10 Main Magnetizing Winding — A coil provided in the permeameter for the magnetization of the test length of the specimen.

2.11 Area Turns — The product of the number of turns (N) of wire in a search coil and the mean effective area (A), in square centimetres enclosed by them, that is $N \times A$.

2.12 Maxwell Turns — The product of the number of turns of wire of a flux search-coil and the number of flux lines passing through them.

2.13 Hysteresis Loss — The energy expended in carrying the material under examination through one complete magnetic cycle.

3. APPARATUS

3.0 The apparatus shall comprise the following:

- a) Permeameter
- b) Control box
- c) Galvanometer
- d) Lamp and Scale
- e) Rheostats
- f) D.C. power supply

Figure 1 gives the general arrangement of the permeameter and control box, and connections between the two internal electrical circuits of the control box are given in Fig. 2.

3.1 Permeameter — Figure 1 shows the permeameter made up of a magnetic core of U-shape, comprising of a yoke portion with core arms C and C , the latter having slotted extensions. The polar faces of the core arms and the extensions are bridged by the specimen, X , under test. Upon the yoke portion of the core is located a magnetizing winding, M . A test coil, B , which encircles the specimen under test, is situated between the ends of the core arms. A second test coil, H , is affixed between the upper ends of two magnetic contact shoes I and I . These two coils are connected to the binding posts B and H , respectively, the connections being detachable. Clamps E serve to hold the test specimen firmly in place between the sheets I and I and the polar faces of the core arms.

3.2 Control Box — The control box comprises an arrangement of switches, galvanometer adjusting resistances, ammeter and calibrating inductance.

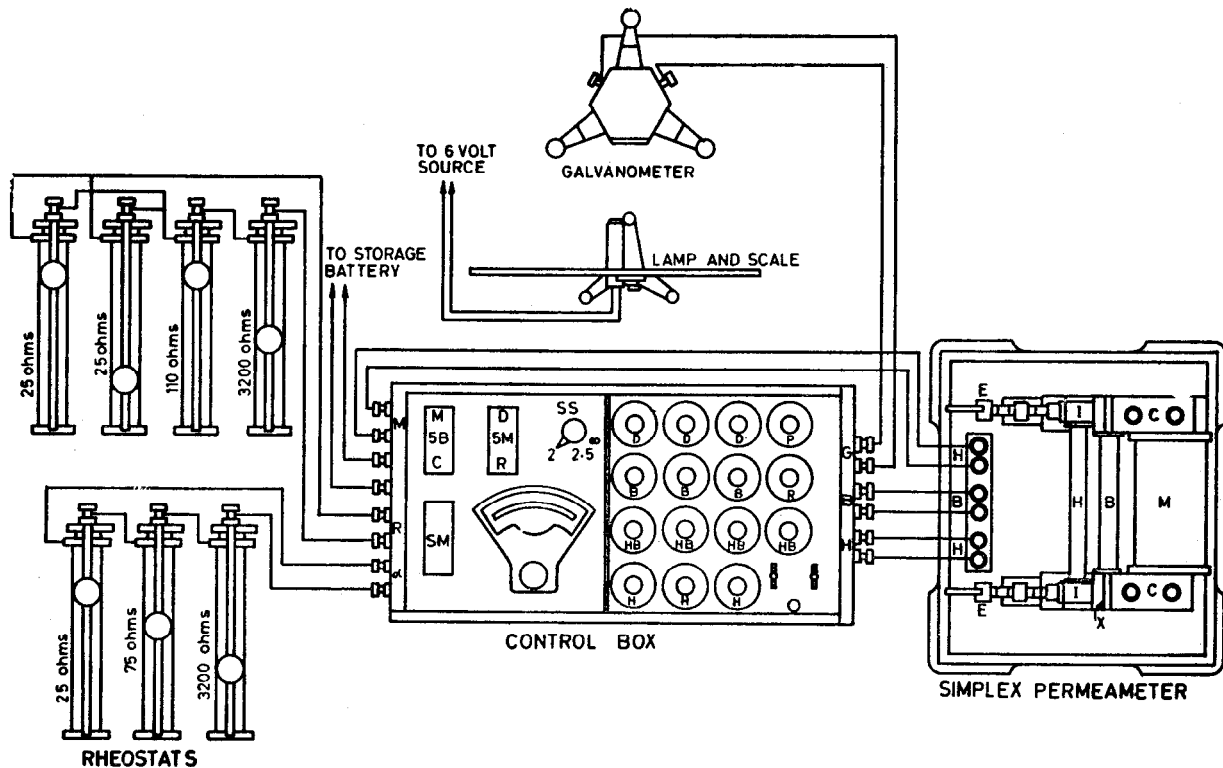
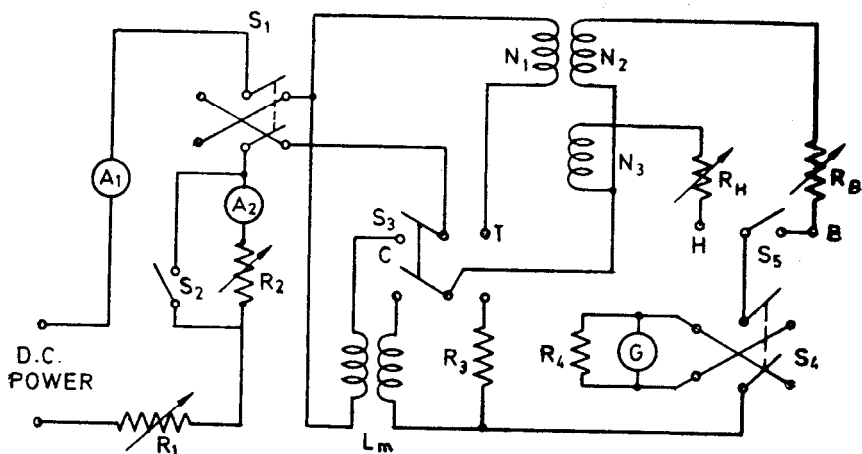


FIG. 1 ASSEMBLY OF FAHY SIMPLEX PERMEAMETER



- A_1 Multirange ammeter (main current)
- A_2 Multirange ammeter (hysteresis current)
- B Indication test position for switch S_5
- C Calibrate position for switch S_3
- G Galvanometer or fluxmeter
- H Magnetizing test position for switch S_4
- L_m Calibrating mutual inductor
- N_1 Magnetizing coil
- N_2 Induction sensing coil
- N_3 Magnetizing force sensing coil
- R_1 Main current control resistors
- R_2 Hysteresis current control resistors
- R_3 Substitution resistor for mutual inductor secondary winding
- R_4 Galvanometer damping resistor
- R_B Induction circuit or fluxmeter calibrating resistor
- R_H Magnetizing circuit calibrating resistor
- S_1 Reversing switch for magnetizing current
- S_2 Shunting switch for hysteresis current control
- S_3 Test-calibrate switch
- S_4 Galvanometer reversing switch
- S_5 Galvanometer circuit test switch
- T Test position for switch S_3

FIG. 2 BASIC CIRCUIT USING PERMEAMETER

3.3 Galvanometer or Fluxmeter — The fluxmeter for measuring induction and magnetizing force may be of either the ballistic-galvanometer or torsionless-fluxmeter types. It should be designed for high fluxlinkage sensitivity. The moving coil should have a free (undamped) period of at least 25 s.

3.3.1 When ballistic galvanometers are to be used it is often difficult to obtain adequate flux-linkage sensitivity. Under these conditions it is better to purchase long-period galvanometers of very high sensitivity to micro-ampere currents and which also have low-resistance moving coils.

3.4 Power Supply — The power supply should be able to supply direct-current power at a steady rate and be capable of quickly returning to this steady rate after a switching operation. Experience has shown that a battery of electrochemical cells of the lead-acid or nickel-iron and other types are acceptable sources when the maximum current and voltage requirements are coordinated with adequate storage capacity and the number of cells respectively. Motor-generator sets or sets or rectifier-filter type supplies may also be used but care should be taken to prevent the occurrence of excessive current reversal times or transient overvoltages which may appear at the time of the test during switching operations. In case rectifier-set is used, ac component of the output voltage shall not exceed 2 mV for 50 volts dc supply. The power supply and its leads should be well isolated from ground by the use of insulators which provide a very high resistance to ground.

4. TEST SPECIMEN

4.1 The test specimens shall consist of straight bars, rods, or strips of uniform cross-section. The cross sectional area shall not be less than 4.00 square centimetres. The length shall be not less than 25 cm and ratio of length to diameter or equivalent diameter shall be as follows:

<i>Permeability</i>	<i>Dimensional Ratio</i>
Under 1.1	4 or over
1.1 to 2.0	20 or over
Over 2.0 to 4.0	30 or over

4.1.1 Under no circumstances the length of the bar shall exceed more than 30 cm.

5. CALIBRATION AND STANDARDIZATION

5.1 Calibration of the Induction Circuit — The calibration of the *B* or induction circuit is determined from the following equation:

$$I_c = BN_B A / (L_m \times 10^5)$$

where

I_c = current required for reversal in L_m to calibrate the *B* circuit, *A*;

B = flux density of calibrated deflection, gaussses;

N_B = number of turns in coil N_2 of Fig. 2;

A = cross-sectional area of test specimen, cm^2 ; and

L_m = mutual inductance of calibrating inductor, mH .

Using this equation, substitute the value of B corresponding to the desired maximum value for a calibrated B value or range. Set the proper value of calculated current and with switch S_1 in the B position reverse this current through the mutual inductor. The value of R_B is then adjusted to make the galvanometer, on current reversal, swing from zero to the desired scale reading.

5.2 Calibration of the H Circuit — The calibration of the magnetizing or H circuit is accomplished by following the above procedures and use of the following equation:

$$I_c = HN_H A_H / (L_m \times 10^5)$$

where

I_c = current required for reversal in L_m to calibrate the H circuit, A ;

H = value of magnetizing force for calibrated deflection oersteds;

N_H = number of turns in coil N_3 , of Fig. 2;

A_H = effective area of coil N_3 , of Fig. 2, cm^2 ; and

L_m = mutual inductance of calibrating inductor, mH .

Using this equation, substitute in the value of H corresponding to the desired maximum deflection for a calibrated H value or range. Set the proper value of calculated current and with switch S_1 in the H position reverse this current through the mutual inductor. The value of R_H is then adjusted to make the galvanometer deflection on current reversal, swing from zero to the desired scale reading.

5.3 Calibration Curves and Scale Deflection Multipliers

5.3.1 When the light-beam path lengths are short or the angle of deflection is large a tangency error may appear in deflection magnitude. The ballistic-galvanometer or fluxmeter deflections shall be examined to determine the deviation from linear behaviour. An instrument whose calibrated deflections over the useful scale range stays within 0.1 percent when compared with the graduations of a linear scale shall be considered to have a linear calibration. Under these conditions a single B or H scale multiplying factor may be used for all of the scale deflection when

deviation from linearity is found to exceed 0.1 percent it may be necessary to calibrate at a number of different scale deflections. These are then combined to provide calibration curves which are correct within 0.1 percent.

5.3.2 For quality control or for material testing where the permeameter is used under conditions which do not require a close precision of test a single scale factor may be used.

6. PROCEDURE

6.1 In Fig. 2 the dc power source supplies either calibrating or testing current measured by ammeter A_1 . Resistors R_1 and R_2 and switches S_1 and S_2 determine the magnitude and direction of the current as required by various operations. In general, three kinds of switching operations are required in ballistic testing. First operation is reversal of magnetizing current direction, without change of magnitude, as required for establishing a cyclic condition and in normal magnetic tests. This is accomplished by throwing switch S_1 from one side to the other. The second operation is reduction of magnitude of magnetizing current without change of direction, which may be done by opening switch S_2 . The third operation combines reversal of direction of magnetizing current with reduction in magnitude, obtained by simultaneously throwing switch S_1 from one side to the other and opening switch S_2 . It should be ensured that S_2 is opened before S_1 is closed for reversal.

6.2 Switch S_3 connects the battery to mutual inductor L_m for calibrating or to the magnetizing coil N_1 for testing, whichever is desired. Switch S_4 connects the galvanometer to the B winding for calibration and measurement of induction, or to the H winding for calibration and measurement of magnetizing force. Resistor R_4 and switch, S_4 are provided for control of galvanometer damping and direction of throw, respectively. Means for calibrating the galvanometer as a fluxmeter and magnetizing force-meter is provided by the mutual inductor L_m and the resistors R_B and R_H . Control and measure the current in L_m with S_3 in the calibrated position in the same way as for current in the magnetizing coil N_1 . Reverse S_1 without change of magnitude. Since this current is usually of small magnitude, ammeter A_1 may have to be a multirange instrument.

6.3 Before test, demagnetize the specimen in the permeameter or by some other acceptable means. Demagnetize by first establishing a magnetizing force sufficiently large to cause induction in the test specimen to reach a point well above the knee of the magnetization curve. Then simultaneously, while continuously operating the reversing switch at half second or longer intervals, slowly reduce the magnetizing current to zero in small increments.

6.4 To obtain a test point, establish the proper magnetizing current then follow the appropriate procedure for the test point. Determine the H and B values of the test point in separate independent measurements at the same value of magnetizing current. Since these measurements are independent either may be determined first without loss of testing accuracy provided the same magnetizing current may be established for both test points.

7. CALCULATIONS

7.1 The sample area shall normally be determined from test specimen mass, length, and density using the equation:

$$A = m/ld$$

where

A = cross-sectional area, cm^2 ;

m = mass of specimen, g;

d = density of material, g/cm^3 ; and

l = specimen length, cm.

In many permeameters the B -coil area is much larger than the test specimen area, when this occurs a correction for air flux in the B -coil is required. (This correction is applicable to ring specimen only.) This correction K shall be made as shown below:

$$K = (a - A)/A$$

where

a = cross sectional area of test coil, cm^2 ; and

A = cross-sectional area of test sample, cm^2 .

$$B = B_{obs} - KT_m H$$

where

B = induction in test specimen, gauss;

H = magnetizing force, oersteds; and

T_m = magnetic constant of free space (in cgs system $T_m = 1$ gauss oersted).

For hysteresis loops:

$$B_{true} = B_m - (B_{obs} - KT_m H)$$

where

B_{true} = induction at the test point on hysteresis curve, gauss.

B_m = maximum value SCM induction for hysteresis, gaussses;

B_{obs} = change in induction from B_m to B_{true} , gaussses;

H = change in magnetizing force, oersteds; and

T_m = magnetic constant of free space (in the cgs system
 $T_m = 1$ gauss/oersted).

8. REPORT

8.1 When normal induction or hysteresis tests are made in a permeameter the following shall be reported along with the test data:

- a) Name or type of permeameter used;
- b) Size and shape of the test specimen;
- c) With hysteresis data, when coercive force residual induction or other specific hysteresis test points are reported, the value of cyclically symmetrical peak magnetizing force or induction is required; and
- d) When values are reported, as those for saturation induction, the corresponding value of magnetizing force should also be reported.